

CLAIMS

What is claimed is:

1. A process for cleaning substrates comprising:
placing the substrates to be cleaned in a cleaning vessel;
5 adding organic solvent to the cleaning vessel;
cleaning the substrates with the organic solvent;
removing a portion of the organic solvent from the cleaning vessel;
placing the substrates in a drying vessel;
adding pressurized fluid solvent to the drying vessel;
10 removing the pressurized fluid solvent from the drying vessel; and
removing the substrates from the drying vessel.
2. The process of claim 1 wherein the substrates being cleaned comprise
15 textiles.
3. The process of claim 2 wherein the cleaning vessel further contains a
rotatable drum within the cleaning vessel into which the textiles are placed.
4. The process of claim 3 wherein removing a portion of the organic
20 solvent from the cleaning vessel further comprises rotating the drum at sufficient
speed to extract the portion of the organic solvent from the textiles.
5. The process of claim 2 wherein removing the pressurized fluid solvent
from the drying vessel further comprises the step of depressurizing the drying vessel
25 to vaporize at least a portion of the pressurized fluid solvent.
6. The process of claim 5 wherein the drying vessel further comprises a
rotatable drum within the drying vessel into which the textiles are placed.
- 30 7. The process of claim 6 wherein removing the pressurized fluid solvent
from the drying vessel further comprises the step of rotating the drum at sufficient

speed to extract a portion of the pressurized fluid solvent from the textiles before the drying vessel is depressurized.

8. The process of claim 1 wherein the organic solvent:

5 is soluble in carbon dioxide between 600 and 1050 pounds per square inch and between 5 and 30 degrees Celsius;

has an evaporation rate of lower than 30 (based on n-butyl acetate = 100);

10 has a dispersion Hansen solubility parameter of between 7.2 (cal/cm³)^{1/2} and 8.1 (cal/cm³)^{1/2};

has a polar Hansen solubility parameter of between 2.0 (cal/cm³)^{1/2} and 4.8 (cal/cm³)^{1/2}; and

15 has a hydrogen bonding Hansen solubility parameter of between 4.0 (cal/cm³)^{1/2} and 7.3 (cal/cm³)^{1/2}.

9. The process of claim 8 wherein the organic solvent further:

has a specific gravity of greater than 0.7; and

has a flash point greater than 200 degrees Fahrenheit.

20 10. The process of claim 9 wherein the pressurized fluid solvent is densified carbon dioxide.

11. The process of claim 1 wherein the organic solvent is a glycol ether.

25 12. The process of claim 1 wherein the organic solvent is a poly glycol ether.

30 13. The process of claim 1 wherein the organic solvent is selected from a group including dipropylene glycol n-butyl ether, tripropylene glycol n-butyl ether, tripropylene glycol methyl ether, and mixtures thereof.

14. The process of claim 1 wherein the organic solvent comprises a combination of organic solvent and pressurized fluid solvent.

5 15. A process for cleaning substrates comprising:
placing the substrates to be cleaned in a vessel;
adding organic solvent to the vessel;
cleaning the substrates with the organic solvent;
removing a portion of the organic solvent from the vessel;
10 adding pressurized fluid solvent to the vessel;
removing the pressurized fluid solvent from the vessel; and
removing the substrates from the vessel.

15 16. The process of claim 15 wherein the substrates being cleaned comprise textiles.

17. The process of claim 15 wherein the vessel further contains a rotatable drum within the vessel into which the textiles are placed.

20 18. The process of claim 17 wherein removing a portion of the organic solvent from the vessel further comprises rotating the drum at sufficient speed to extract the portion of the organic solvent from the textiles.

25 19. The process of claim 17 wherein removing a portion of the pressurized fluid solvent from the vessel further comprises the step of depressurizing the vessel to vaporize the remaining pressurized fluid solvent.

30 20. The process of claim 19 wherein removing a portion of the pressurized fluid solvent from the vessel further comprises the step of rotating the drum at sufficient speed to extract a portion of the pressurized fluid solvent from the textiles before the vessel is depressurized.

21. The process of claim 15 wherein the organic solvent:
is soluble in carbon dioxide between 600 and 1050 pounds per square
inch and between 5 and 30 degrees Celsius;
has an evaporation rate of lower than 30 (based on n-butyl acetate =
5 100);
has a dispersion Hansen solubility parameter of between 7.2
(cal/cm³)^{1/2} and 8.1 (cal/cm³)^{1/2};
has a polar Hansen solubility parameter of between 2.0 (cal/cm³)^{1/2} and
4.8 (cal/cm³)^{1/2}; and
10 has a hydrogen bonding Hansen solubility parameter of between 4.0
(cal/cm³)^{1/2} and 7.3 (cal/cm³)^{1/2}.
22. The process of claim 21 wherein the organic solvent further:
has a specific gravity of greater than 0.7; and
15 has a flash point greater than 200 degrees Fahrenheit.
23. The process of claim 22 wherein the pressurized fluid solvent is
densified carbon dioxide.
- 20 24. The process of claim 15 wherein the organic solvent is a glycol ether.
25. The process of claim 15 wherein the organic solvent is a poly glycol
ether.
- 25 26. The process of claim 15 wherein the organic solvent is selected from a
group including dipropylene glycol n-butyl ether, tripropylene glycol n-butyl ether,
tripropylene glycol methyl ether, and mixtures thereof.
- 30 27. The process of claim 13 wherein the organic solvent comprises a
combination of organic solvent and pressurized fluid solvent.

28. A process for cleaning textiles comprising:

placing the textiles to be cleaned into a cleaning drum within a cleaning vessel;

adding organic solvent to the cleaning vessel;

5 cleaning the textiles with the organic solvent;

removing a portion of the organic solvent from the cleaning vessel;

rotating the cleaning drum to extract a portion of the organic solvent from the textiles;

10 placing the textiles into a drying drum within a pressurizable drying vessel;

adding pressurized fluid solvent to the drying vessel;

removing a portion of the pressurized fluid solvent from the drying vessel;

15 rotating the drying drum to extract a portion of the pressurized fluid solvent from the textiles;

depressurizing the drying vessel to remove the remainder of the carbon dioxide by evaporation; and

removing the textiles from the drying drum.

20 29. A system for cleaning substrates comprising:

a cleaning vessel adapted to hold contaminated substrates and organic solvent;

an organic solvent tank operatively connected to the cleaning vessel;

25 a pump for pumping organic solvent from the organic solvent tank to the cleaning vessel;

a drying vessel adapted to hold cleaned substrates and pressurized fluid solvent;

a carbon dioxide tank operatively connected to the drying vessel; and

30 a pump for pumping pressurized fluid solvent from the carbon dioxide tank to the drying vessel.

30. The system of claim 29 wherein the substrates comprise textiles.

31. The system of claim 30 wherein the cleaning vessel further comprises a rotatable drum within the cleaning vessel adapted to hold textiles.

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32. The system of claim 31 wherein the rotatable drum is adapted to rotate at sufficient speed to extract a portion of the organic solvent from the textiles.

33. The system of claim 30 wherein the drying vessel further comprises a rotatable drum within the drying vessel adapted to hold textiles.

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34. The system of claim 33 wherein the rotatable drum is adapted to rotate at sufficient speed to extract a portion of the pressurized fluid solvent from the textiles.

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35. The system of claim 29 wherein the organic solvent:

is soluble in carbon dioxide between 600 and 1050 pounds per square inch and between 5 and 30 degrees Celsius;

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has an evaporation rate of lower than 30 (based on n-butyl acetate = 100);

has a dispersion Hansen solubility parameter of between 7.2 (cal/cm³)^{1/2} and 8.1 (cal/cm³)^{1/2};

has a polar Hansen solubility parameter of between 2.0 (cal/cm³)^{1/2} and 4.8 (cal/cm³)^{1/2}; and

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has a hydrogen bonding Hansen solubility parameter of between 4.0 (cal/cm³)^{1/2} and 7.3 (cal/cm³)^{1/2}.

36. The system of claim 35 wherein the organic solvent further:

has a specific gravity of greater than 0.7; and

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has a flash point greater than 200 degrees Fahrenheit.

37. The system of claim 36 wherein the pressurized fluid solvent is densified carbon dioxide.

38. The system of claim 29 wherein the organic solvent is a glycol ether.

39. The system of claim 29 wherein the organic solvent is a poly glycol ether.

40. The system of claim 29 wherein the organic solvent is selected from a group including dipropylene glycol n-butyl ether, tripropylene glycol n-butyl ether, tripropylene glycol methyl ether, and mixtures thereof.

41. A system for cleaning substrates comprising:

a vessel adapted to hold substrates, organic solvent, and pressurized fluid solvent;

an organic solvent tank operatively connected to the vessel;

a pump for pumping organic solvent from the organic solvent tank to the vessel;

a pressurized fluid solvent tank operatively connected to the vessel;

and

a pump for pumping pressurized fluid solvent from the pressurized fluid solvent tank to the vessel.

42. The system of claim 41 wherein the substrates comprise textiles.

43. The system of claim 42 wherein the vessel further comprises a rotatable drum within the vessel adapted to hold textiles.

44. The system of claim 43 wherein the rotatable drum is adapted to rotate at sufficient speed to extract a portion of the organic solvent and a portion of the pressurized fluid solvent from the textiles.

45. The system of claim 41 wherein the organic solvent:

is soluble in carbon dioxide between 600 and 1050 pounds per square inch and between 5 and 30 degrees Celsius;

5 has an evaporation rate of lower than 30 (based on n-butyl acetate = 100);

has a dispersion Hansen solubility parameter of between 7.2 (cal/cm³)^{1/2} and 8.1 (cal/cm³)^{1/2};

10 has a polar Hansen solubility parameter of between 2.0 (cal/cm³)^{1/2} and 4.8 (cal/cm³)^{1/2}; and

has a hydrogen bonding Hansen solubility parameter of between 4.0 (cal/cm³)^{1/2} and 7.3 (cal/cm³)^{1/2}.

46. The system of claim 45 wherein the organic solvent further:

15 has a specific gravity of greater than 0.7; and

has a flash point greater than 200 degrees Fahrenheit.

47. The system of claim 46 wherein the pressurized fluid solvent is densified carbon dioxide.

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48. The system of claim 41 wherein the organic solvent is a glycol ether.

49. The system of claim 41 wherein the organic solvent is a poly glycol ether.

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50. The system of claim 41 wherein the organic solvent is selected from a group including dipropylene glycol n-butyl ether, tripropylene glycol n-butyl ether, tripropylene glycol methyl ether, and mixtures thereof.

51. A system for cleaning textiles comprising:

a cleaning vessel adapted to retain textiles and organic solvent and able to agitate the textiles and the organic solvent;

an organic solvent tank operatively connected to the cleaning vessel;

5 a drying vessel adapted to retain textiles and pressurized fluid solvent and able to agitate the textiles and the pressurized fluid solvent; and

a pressurized fluid solvent tank operatively connected to the drying vessel.

10 52. A system for cleaning textiles comprising:

a pressurizable vessel adapted to retain textiles and organic solvent and pressurized fluid solvent and able to agitate the textiles and the organic solvent and the pressurized fluid solvent;

15 an organic solvent tank operatively connected to the pressurizable vessel; and

a pressurized fluid solvent tank operatively connected to the pressurizable vessel.

53. A system for cleaning substrates comprising:

20 a cleaning vessel adapted to hold contaminated substrates and organic solvent;

an organic solvent tank operatively connected to the cleaning vessel and containing organic solvent;

25 means for moving organic solvent from the organic solvent tank to the cleaning vessel;

a drying vessel adapted to hold cleaned substrates and pressurized fluid solvent;

a pressurized fluid solvent tank operatively connected to the drying vessel and containing pressurized fluid solvent; and

30 means for moving pressurized fluid solvent from the pressurized fluid solvent tank to the drying vessel.

54. The system of claim 53 wherein the substrates comprise textiles.

55. The system of claim 54 wherein the cleaning vessel further comprises an agitation means for agitating the cleaning vessel adapted to hold textiles and the organic solvent.

56. The system of claim 55 wherein the agitation means is adapted to agitate the cleaning vessel to extract a portion of the organic solvent from the textiles.

57. The system of claim 54 wherein the cleaning vessel is adapted to depressurize so as to vaporize at least a portion of the pressurized fluid solvent.

58. The system of claim 53 wherein the organic solvent:
is soluble in carbon dioxide between 600 and 1050 pounds per square inch and between 5 and 30 degrees Celsius;
has an evaporation rate of lower than 30 (based on n-butyl acetate = 100);
has a dispersion Hansen solubility parameter of between 7.2 (cal/cm³)^{1/2} and 8.1 (cal/cm³)^{1/2};
has a polar Hansen solubility parameter of between 2.0 (cal/cm³)^{1/2} and 4.8 (cal/cm³)^{1/2}; and
has a hydrogen bonding Hansen solubility parameter of between 4.0 (cal/cm³)^{1/2} and 7.3 (cal/cm³)^{1/2}.

59. The system of claim 58 wherein the organic solvent further:
has a specific gravity of greater than 0.7; and
has a flash point greater than 200 degrees Fahrenheit.

60. The system of claim 59 wherein the pressurized fluid solvent is densified carbon dioxide.